4.6 Ce[redacted]re pivot and lateral move machines

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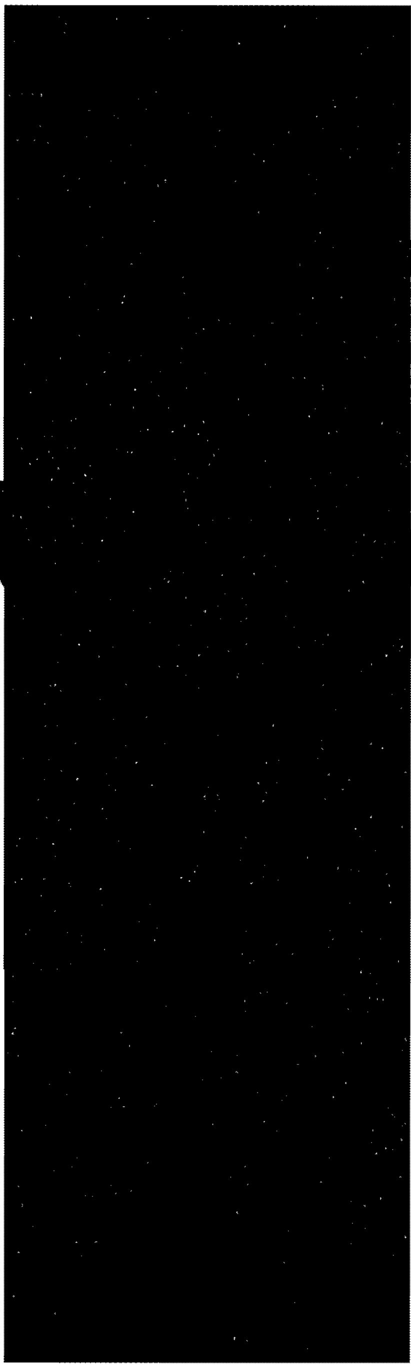


History of centre pivot and lateral move machines

Centre pivot and lateral move irrigation machines (CP&LMs) represent the largest (in both physical size and flow rate) of the mobile machines used by growers to apply water to crops and fields. The first CP&LMs were developed in the late 1940s with the patenting of a 'self-propelled sprinkling irrigation apparatus' by Frank Zybach in Nebraska. A.E. Trowbridge manufactured these early machines. Prior to this time, sprinkler irrigation was commonly performed using steel pipe and impact sprinklers, as aluminium pipe was only just becoming available. These early centre pivot machines consisted of towers that supported the pipes via suspension cable and were powered by the irrigation water pressure using hydrostatic drives at each wheel set. The right to manufacture these machines was acquired in the 1950s by Robert Daugherty who began manufacturing under the 'Valley' brand name. The first Australian innovation in this arena saw the Layne and Bowler Company of the USA introduce the Australian Raincat ideas of electric motor drives, today's standard bowstring truss suspension and track drives which were later replaced with rubber tyres. During the 1960s, machines also started to be manufactured with water piston or water spinner drives rather than oil hydraulic drives. The standard machine manufactured prior to 1970 was a high-pressure unit (~80 psi at the centre) fitted with large impact sprinklers located along the top of pipe. However, the energy crisis in the early 1970s resulted in the introduction of low-pressure static plate sprinklers located on droppers below the pipe. These modifications meant that the machines could be operated at much lower pressures (<40 psi) with lower operating costs.

By the mid-1970s, centre pivot and lateral move machines were rapidly starting to dominate the new and expanding irrigation developments in the USA and the Middle East. Of the 25.6 million hectares currently irrigated in the USA, approximately 32% (or 8.1 million hectares) is irrigated with this equipment. Centre pivots were first introduced into Australia in the 1960s, primarily in South Australia and Victoria. Centre pivot and lateral move machines currently irrigate 8% to 10% of the total irrigated area in Australia. Centre pivot irrigation of cotton has been undertaken in the USA since the late 1960s and in Australia since the early 1970s.

The last thirty years have seen the four main CP&LM manufacturing companies based in Nebraska (Valley, Lindsay Zimmatic, T&L, and Reinke) dominate the world market for these machines. There are approximately 350 machines sold in Australia each year and around thirteen manufacturers or distributors. However, the majority of the machines available in Australia are manufactured in either the USA or Europe, with only a handful being manufactured by Australian companies. In most cases, common components such as electric motors, gearboxes and control panels are imported, with pipes, framework and other major structures manufactured locally. Not all of the manufacturers build lateral move machines. In particular, USA-based companies are often not interested in the manufacture of lateral move machines due to the comparatively small market size and the additional level of complexity associated with controlling and guiding these machines, yet they remain the only suppliers.

The expansion of the area irrigated by CP&LMs in the USA resulted in a substantial research and development effort focused on the appropriate design and management practices for these machines. The USDA - Agricultural Research Service and the extension centres located in the state universities conducted much of this work. The most relevant work for Australian cotton growers has been undertaken by Texas A&M University in areas where cotton is grown with limited water supplies using these machines. However, very little research and development work has been conducted on CP&LMs under Australian conditions.

Equipment overview

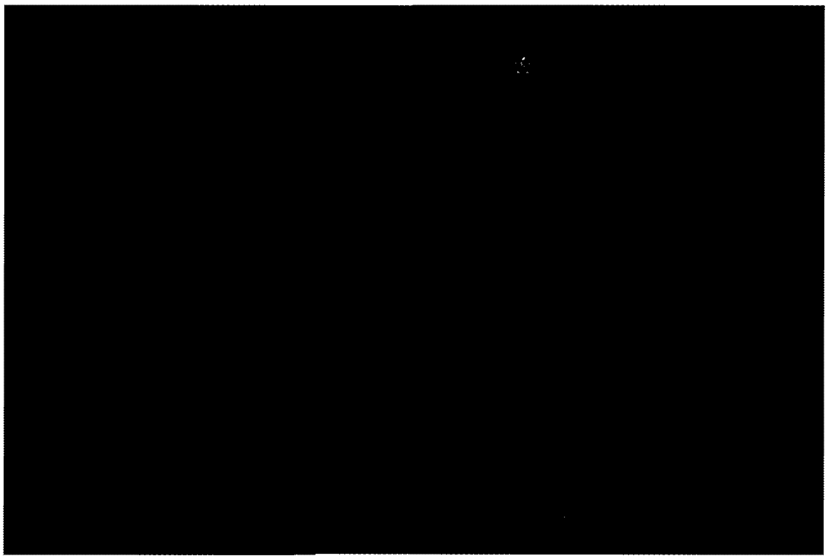
Centre pivot systems are usually no longer than 500 metres, with the most common size being around 400 metres long. Lateral move machines are not commonly used overseas, and, when used in other crops, are rarely greater than 500 m long. The popularity of large machines in the cotton industry has resulted in lateral move machines of up to 1000 m in length being installed locally.

The main components of these CP&LMs are the self-supporting frame spans. These structures use the water delivery pipes (located along the backbone of the span) as compression members that are held together by tie-rods acting as tension members. The pipe spans are supported at each end by a tower that incorporates gearboxes, drive wheels and either an electric or a hydraulic drive motor. Emitters (either sprinkler heads or low energy precision application fittings) are attached either directly to sockets on the main pipe or suspended closer to the crop on either rigid or flexible droppers.

Flexible mechanical and hydraulic couplings that allow the separate spans to act as individual elements connect individual spans. This ensures flexing, rotating and twisting of the joint and spans so that the machine can traverse land contours and obstacles. Machine speed governs the volume (depth) of water applied in each pass, while system alignment is maintained via micro switches, alignment levers and control equipment.

Centre pivots consist of a number of spans attached to a fixed centre tower containing a water supply point and power source around which the other spans and towers rotate (Figure 4.6.1). Lateral move machines are constructed in a manner similar to centre pivot machines except that they do not have a central rigid supply point: instead, they have the water supply point located either in the middle or at one end of the machine on a cart-tower assembly containing a mobile power plant. Lateral move machines that are supplied from open channels are provided with a large lift pump, while hose-supplied systems are fitted with an attachment point for connection to the watermain hydrant via a flexible water delivery hose.

Figure 4.6.1. Centre pivot irrigation machine showing centre tower, spans, and wheel towers



Spans and pipe sizes

Spans commonly range in length from 34.2 m (113 ft) to 62.4 m (206 ft) with variations in exact size between different manufacturers. Span lengths are commonly limited due to the weight associated with the pipe itself and the volume of water transported. Internal diameters of the span pipes range from 135 to 247.8 mm, with the most common pipe sizes being 162, 197 and 213 mm. Typical pipe wall thickness is about 2.77 mm for these systems.

Types of emitters

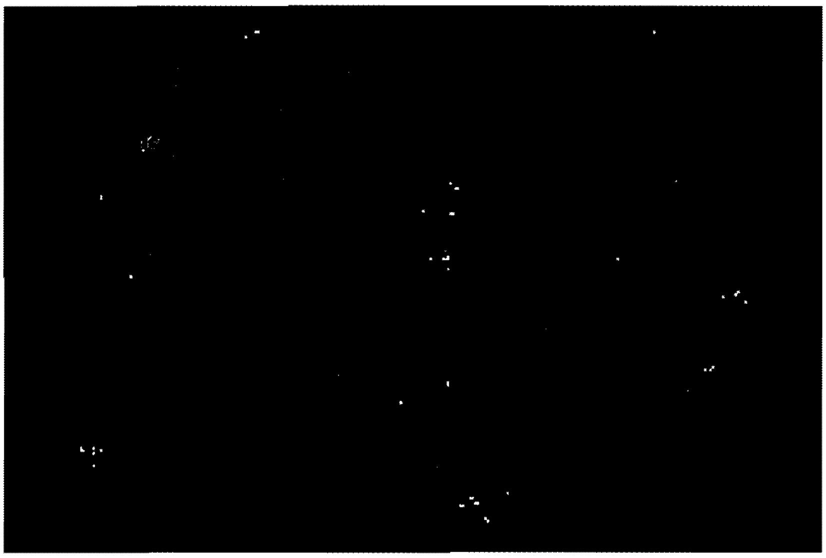
There are a wide range of emitter nozzles and application heads currently available for CP&LMs. The application heads can be broadly grouped into either low energy precision application (LEPA) attachments or sprinklers. LEPA systems apply water at low pressure either directly onto the soil surface or below the crop canopy to eliminate sprinkler evaporation from the plant canopy and drastically reduce the wetted soil surface and soil surface evaporation. These systems commonly operate at very low pressures (10-20 psi) and, hence, have reduced pumping energy costs. Although LEPA systems have been in existence since the mid 1980s, the adoption of these application heads in Australia has been slow.

LEPA application heads are available as either a drag sock or a combination head known as the 'Quadspray' or bubbler (Figure 4.6.2). Both types of head are commonly suspended from the main pipe by flexible hose at either one or two crop row intervals. Drag socks come in both double- and single-ended sock options. Double-ended socks are used in conjunction with furrow dykes or tied ridge structures to reduce the risk of washing these structures away (Figure 4.6.3). The 'Quadspray' unit has four operating modes that allow water to be either bubbled out in a low-pressure circular sheet, sprayed horizontally (germination mode), sprayed vertically upward (chemigation mode) or dribbled out directly from the bottom (Figure 4.6.4). Changeover from one operational mode to another only involves a click and twist rotation.

Drag socks are replaced with static plate sprinklers for crop germination and are positioned well above the soil surface to ensure good sprinkler overlap. When using the static plate sprinklers for germination, LEPA head hose lengths need to be either reduced or slung over the pipe to gain the height typically needed for the sprinkler throw. Hence, where any LEPA system is employed, there are requirements for both time and labour after crop establishment to allow a changeover from the static plate sprinklers to the LEPA heads.

Figure 4.6.2. Emitter options for low energy precision application

(a) Drag sock



(b) Quadspray in bubbler mode

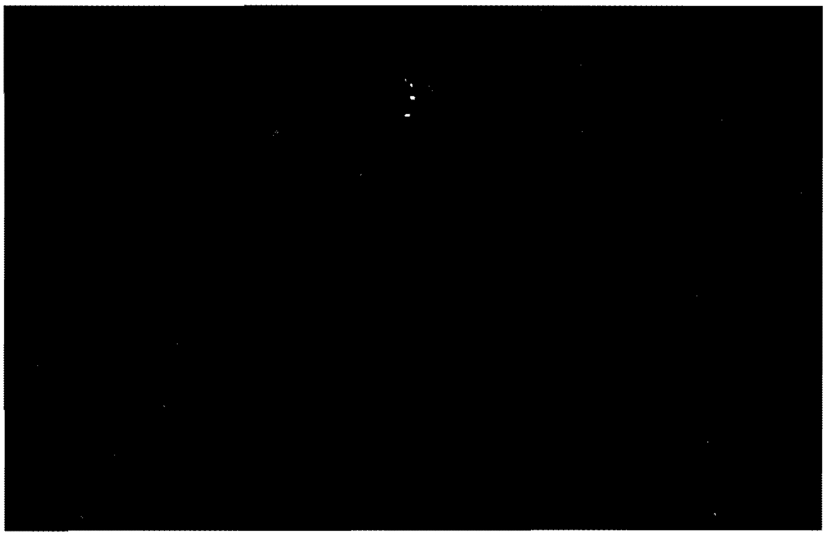
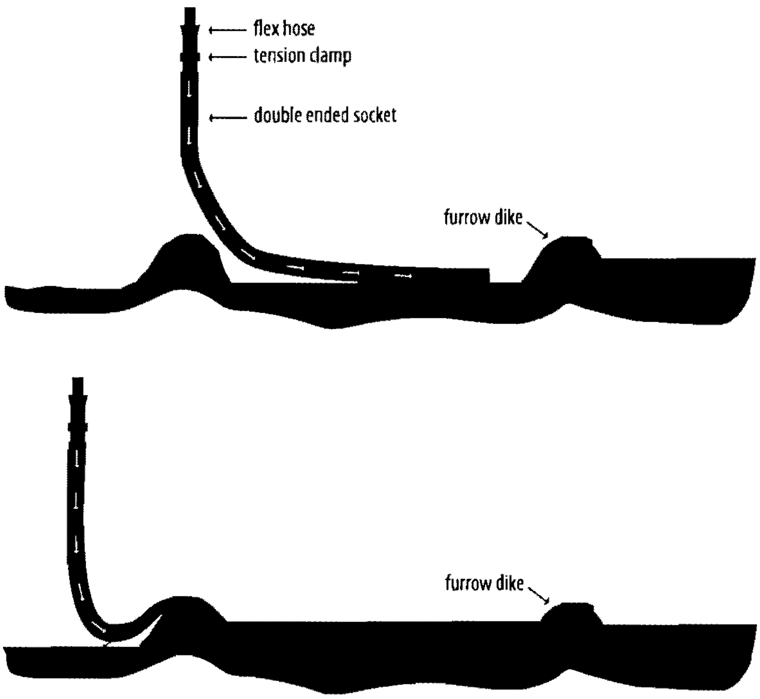
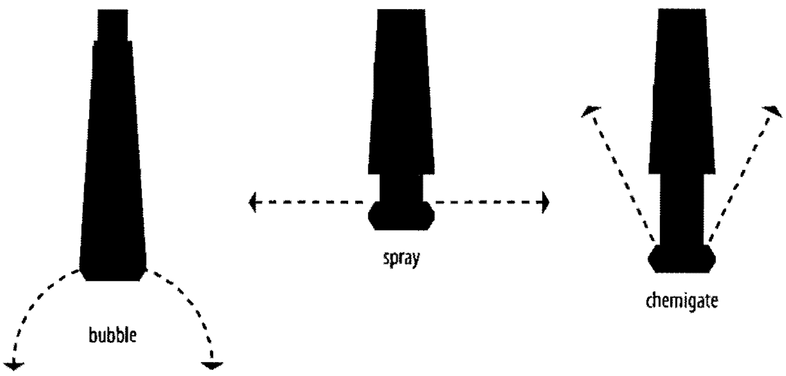


Figure 4.6.3. Operation of a double-ended LEPA drag sock in conjunction with furrow dykes



Source: New and Fipps 1990

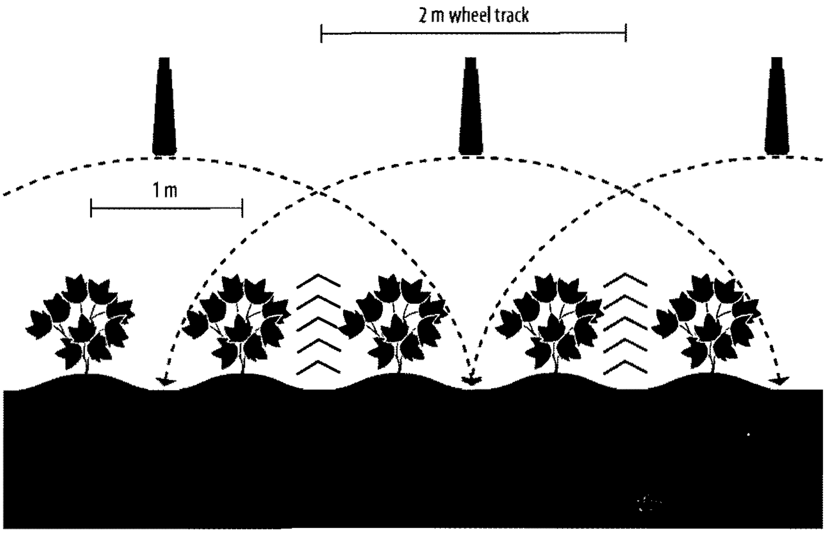
Figure 4.6.4. Operational modes for Quadspray LEPA heads



Source: New and Fipps 1990

Sprinklers are widely used on CP&LM machines and are typically offered as standard fittings. While overhead and top-of-pipe sprinklers were common on older machines, newer machines are typically configured with over-crop sprinklers that hang down from the pipe (Figure 4.6.5). These over-crop sprinkler heads are available as either static or moving plate sprinkler heads. Static plate heads do not have any moving parts but use a range of groove configurations upon a plate to produce the streamlets. Various static plates configurations are available to alter the number of streamlets and the angle of streamlet throw. Moving plate sprinkler heads represent the newer generation of heads that have been steadily increasing the number of streamlets while maximizing throw distances.

Figure 4.6.5. Over-crop sprinkler irrigation



The different types of moving plate devices available include spinners (low operating pressure but fast rotation), rotators (higher operating pressure but slower rotation) and wobblers (medium to low pressure with multi-path streamlets). All of these heads are typically suspended on rigid dropper pipes that hold the sprinkler head at spacings of 2.4 to 3.0 m (8 to 10 ft), and at a height just above the full crop height. While this form of sprinkler head and configuration is the most simple to design and use, it does suffer from evaporative losses (particularly during peak evaporation periods) associated with soil and plant surface evaporation, and these losses must be taken into account when designing the system capacity.

It is generally accepted that the replacement of older sprinkler technologies (both top-of-pipe and static head over-crop sprinklers) on existing CP&LMs is a relatively simple and cost-effective way of improving system performance. In general, the larger the number of streamlets produced by the emitter, the smaller the droplet size and the lower the drop impact energy applied to the soil surface.

However, the lower the sprinkler head pressure, the larger the droplet size. Modern low-pressure sprinklers impart roughly 60% of the energy of old top-of-pipe high-pressure impact sprinklers (Kincaid 1996). Low pressures and large numbers of streamlets typically provide the best result in terms of reducing the instantaneous application rate, reducing the impact energy imparted to the soil and increasing the throw distance. These benefits typically minimise surface crusting and reduce run-off.

Each emitter (either sprinkler or LEPA attachment) on a centre pivot is positioned at a greater radial distance from the centre and must provide water for an increasingly sized concentric ring of field area. This is achieved by either increasing the nozzle size and maintaining the nozzle spacing or, alternatively, maintaining the same nozzle size and decreasing the emitter spacing as the radius increases. Sprinkler spacing is not altered along the length of lateral move machines, with little if any increase in nozzle size.

Boombacks

Boombacks are used to suspend the emitters at a distance of 3 to 6 m behind the machine towers (Figure 4.6.6). These optional fittings are used to improve the uniformity of sprinkler application to the crop near the towers and to reduce the potential for irrigation water intercepted by the tower (Figure 4.6.7) causing either rutting or bogging. Where the machine is required to move in both directions, boombacks can be fitted to both sides of the tower with the appropriate set of emitters selected using either manual or automated valves. Alternatively, a single boomback mounted on a hinged fitting can be used and swung either side of the towers, depending on the direction of travel.

Figure 4.6.6. Fixed and swivel mounted boombacks for CP&LMs 1 m

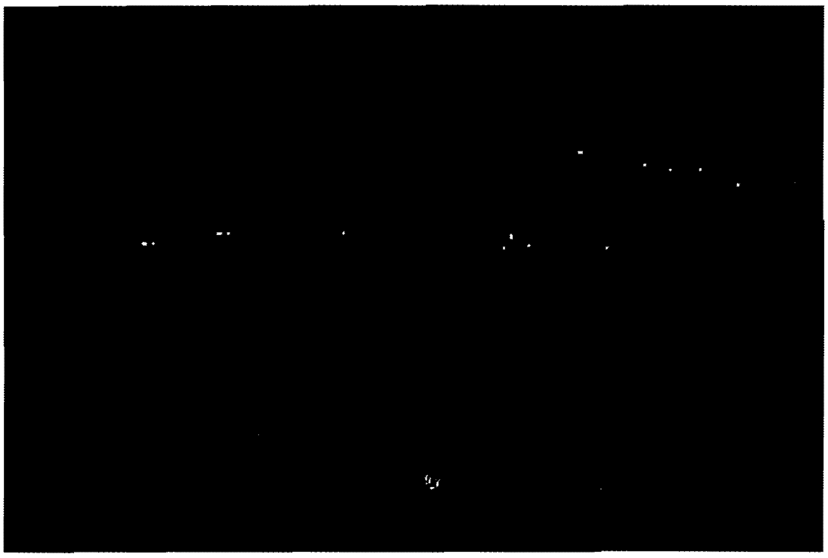
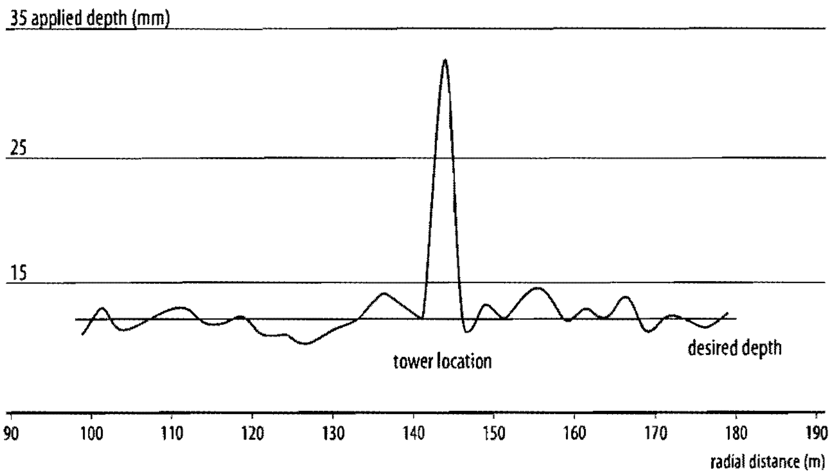


Figure 4.6.7. Field test results showing three times the normal amount of water being applied around the tower through interception of sprinkler water by tower structure



Source: Foley 2000

Tyres and wheel sizes

CP&LMs represent a considerable investment in tyres and wheels, so growers should also ensure that they have the necessary equipment to re-inflate, replace or otherwise repair tyres on the machine. This typically involves having spare tyres, along with lightweight jacks and blocks.

Larger tyre sizes are sold as options to reduce wheel rut formation. Common tyre sizes for centre pivot and lateral move machines include 14.9' x 24', 16.9' x 24', 16.9' x 28' and 11.2' x 38'. However, these sizes result in ground pressures for a wet 48 m span (weight ~ 3750 kg) with a 100 mm deep wheel rut of 12.9, 11.4, 10.8 and 14.6 psi respectively. Hence, while there are some differences in ground pressure associated with changes in tyre size, larger tyres do not generally reduce rutting as much as boombacks, which reduce the wetting of the wheeltrack area. Larger wheel and tyre sizes also increase loading upon gearboxes and drive trains. Tyre wheel combinations can also be purchased in sizes up to 18.4' x 28', 16.9' x 34' and 16.9' x 38'. However, manufacturers do not normally like to supply these larger sizes because of the higher drive train loads involved.

High speed ratios are also sometimes sold as solutions to wheel rutting problems. However, high speed drive-train combinations may produce start-up torques that are greater than the design specification for the machine, leading to increased occurrences of motor burnout. Gearbox failures are also often the result of overloading the machine drive-train. Larger width tyres may result in tyre centrelines that overhang from the gearbox attachment points, thus increasing the risk of failure. Where larger and wider tyres are used, the power cable size and hydraulic lines should be increased in capacity to cope with the greater power requirements.

Automation

Control panels vary in complexity depending on requirements. Where necessary, all functions can be manually controlled. Features that are commonly available include machine remote control using either computers or mobile phones with voice feedback and programs to apply varying amounts of water over different periods. It is possible to program the machines to stop where required or vary the application across the field. For lateral move machines, it is possible to progressively apply lighter amounts of water and then to reverse direction at the end of the field, applying increasingly larger amounts of water.

Pressure switches are commonly incorporated to stop pumps when pipes burst (that is, on low pressure) or to start the machine moving when water pressure builds up. Hydraulically driven machines often employ electric over hydraulic controls to perform the more complex tasks of automation. Automation is essential to take full advantage of the CP&LMs' capacities. While automation may increase the machine complexity, it can substantially reduce the time involved in management and provides the level of control required to maximise the return on investment.

Chemigation

Chemigation using CP&LMs can be conducted in two distinct ways. Chemical can be injected into the irrigation water in the main pipe for distribution through the emitters with the water. Products that can be distributed in the irrigation include fertilisers, herbicides, insecticides, and fungicides. Alternatively, chemigation can be conducted using a separate system of distribution pipes with spray heads suspended underneath the CP&LM truss rods to enable the application of chemical with or without irrigation water.

Measuring the performance of CP & LM machines

The three most important measures of CP&LM performance are application rate, uniformity of application and application efficiency. This section explains the importance of each measure and outlines the design and management factors that influence the relevant machine performance variable.

Application rate

Three measures of the application rate are important: the system capacity, the average application rate (AAR) and the instantaneous application rate (IAR). These measures differ primarily in the time scale being considered: system capacity measures are commonly reported as volumes applied per day or week, the average application rate reported as volumes per hour, and instantaneous rates reported as volumes per second.

System capacity: The system capacity of a CP&LM machine is the average daily flow rate of water pumped by the machine divided by the area of that irrigated crop field. It is expressed in the units of millimetres per day, so that it can be directly compared with the peak crop evapotranspiration rate. Alternative units for system capacity would be in ML/ha × 10^2/day (that is, ML per hundreds of hectares per day). System capacity is the maximum possible rate at which the CP&LM can apply water to the chosen area of irrigated field. It is **not** the amount of water that the machine applies per irrigation pass.

Dealers and manufacturers commonly use system capacity for their calculations and their assumption is that the pump is running for 24 hours a day, seven days a week, providing 168 hours a week pump running time.

The system capacity (in millimetres per day) is calculated by converting the CP&LM's pump flow rate into litres per day, and dividing by the irrigated field area in square metres. Remember, 1 litre over 1 square metre equals 1 millimetre depth of water applied. Alternately, growers can calculate the system capacity (mm/day) by taking the megalitres per day pumped onto the irrigated field and dividing by the irrigated area in hundreds of hectares.

The design and management issues associated with the system capacity are often not well understood by Australian growers using these machines and account for many of their perceived failures.

Average application rate: The average application rate (AAR) is the average depth of water applied to the irrigated field during the irrigation. The AAR is calculated by dividing the emitter flow rate (in litres per hour) by the wetted soil surface area (in square metres). The AAR is normally reported in millimetres applied per hour, to allow for a direct comparison with soil infiltration rates.

AAR is altered when emitter wetted area or flow rate is changed. The wetted area is affected by sprinkler height, wind, and sprinkler impact plate changes. Nozzle pressure, nozzle size and sprinkler spacing affect individual sprinkler flow rates.

The introduction of low-pressure fixed sprinkler plate technology in the 1960s and 1970s resulted in increases in AARs because the area wetted by the sprinklers was smaller than that with the previous higher-pressure sprinklers. However, the more recent development of rotators, wobblers, spinners and other moving plate sprinklers have resulted in a substantial decrease in AARs due to the larger throw and greater average droplet diameter of these emitters.

For centre pivot machines, the highest AAR is found at the outer end of the machine. AAR will always be greatest at the outer ends of centre pivots equipped with only one type of emitter and nozzle, as individual emitter flow rates increase in response to the larger annular area irrigated. The AAR of lateral move machines will be lower than the AAR at the outer ends of centre pivots. Individual emitter flow rates on a lateral move will be much smaller than an emitter located on the outer end of a centre pivot that has a similar irrigated area and managed system capacity.

Considerable research in the USA has been conducted upon the common mismatch of AAR and soil infiltration rates at the outer ends of centre pivot machines. For example, Scherer (1998) showed that sprinklers that throw to a radius of 10 metres, sited on the end of a 400 metre long centre pivot, produce average and peak application rates in the order of 40 and 50 mm/h, respectively. When these AARs are compared to the 5 mm/h average infiltration rates common for many clay soils, it is inevitable for the resulting excess water to be temporarily stored in surface roughness or run-off. This is supported by a range of work which suggests that the AAR associated with low pressure sprinklers on the outer ends of centre pivots will commonly exceed the infiltration rate of all soils except sands (for example, Kincaid et al. 2000; King and Kincaid 2001). Other options to reduce surface run-off under these conditions include retaining crop stubble, using spreader bars to increase separation between emitters and using long throw spray emitters.

Instantaneous application rate: The instantaneous application rate (IAR) describes the rate at which water is applied by an individual streamlet from an emitter head to a very small area of irrigated field (for example, hundredths of a square metre). The time scale under consideration for determination of IAR is in the range of seconds and the IAR is typically 1.3 to 1.5 times greater than the AAR (Kincaid et al. 2000). High IARs are commonly recorded where streamlets from static plate sprinklers impact upon a small portion of irrigated field during the stop cycle of electrically driven centre pivots. However, there will be zones of high IAR within the wetted area of every sprinkler pattern.

IARs under CP&LMs are rarely measured in the field. However, the genesis of larger run-off issues is contained in this small area and time scale. Puddling of the soil surface begins from the impact of the streamlets, and is rapidly followed by soil surface sealing through the rearrangement of the destroyed soil crumbs. Most CP&LMs in this country are equipped with rotating, spinning and oscillating plate sprinklers that overcome the high IAR by not having individual streamlets that apply water to any one point. Irrigator concern regarding droplet impact energy (Stillmunkes and James 1982) creating soil crusting issues during germination has led manufacturers to develop specific sprinklers to help germination.

Uniformity of application

Uniformity of application refers to how evenly the irrigation water is applied across the field. In fields not watered uniformly, some parts will be irrigated to the desired depth, while other parts will be either under- or over-irrigated. These non-uniformities lead to yield variation across the irrigated area, resulting in differences in economic return for different portions of the field (Solomon 1988). The factors that contribute to non-uniformity include:

- emitter spacing, nozzle operating pressure, and emitter configuration
- nozzle size and selection with location along machine
- nozzle height, angle and wear
- machine movement including step size and its consistency
- flow rate variations due to discontinuous end-gun operation, and variations in pump duty, and
- run-off from high application rates.

Large nozzle gun sprinklers, which are commonly positioned on the ends of CP&LMs, are also often responsible for the poor uniformity performance of application (Molle 1999). Poor uniformity around wheel towers on CP&LMs is also a common problem, as growers and distributors often employ inappropriate techniques to reduce wheel bogging, resulting in lower uniformity and application rates in the vicinity of the wheel towers.

As CP&LMs do not irrigate all parts of the field at any one instant, they must apply the same depth of water along their travel path and machine length to irrigate uniformly. This requires a different evaluation methodology from that employed on static sprinkler systems. Measurements are commonly taken along one or two transects across their travel path. However, this always results in an underestimate of the uniformity, because no measure of the variation along the direction of travel is obtained. To adequately determine uniformity across the whole field, monitoring is necessary along the full travel path of the machine.

While standards for testing the spatial uniformity are available (for example, ISO11595; ASAE S436) there is still some debate over the appropriateness of the methodology employed in these standards.
The dependence of uniformity measures upon sampling spacings (for catch-can layouts) has been discussed by Smith and Black (1991). On the basis of sampling theory, they recommended that catch can spacings should be of the order of ¼ of the sprinkler spacing (Smith 1995). Bremond and Molle (1995) likewise analysed catch-can spacing and determined that assessment errors could be minimised and catch-can spacings maximised when 5 m spacings were used for CP&LMs with sprinkler wetted diameters of 20 metres.

Two coefficients are commonly used to express the uniformity of irrigation systems - distribution uniformity (DU) and uniformity coefficient (Cu). The DU is an empirical index that is calculated as the ratio, expressed as a percentage, of the mean of the lowest one-quarter of applied depths and the mean of all applied depths:

$$DU\,(\%) = \frac{\bar{x}_{lowerquarter}}{\bar{x}} \times 100$$

where $\bar{x}_{lowerquarter}$ equals the mean of the lowest 25% of individual catch-can depths and $\bar{x}$ equals the mean of all individual catch-can depths. The uniformity of application for solid set impact sprinklers has traditionally been considered acceptable if the calculated DU is greater than 75%. However, Bremond and Molle (1995), Heermann (1991) and Yonts et al. (2000b) have suggested that DU should be greater than 90% for CP&LMs to be considered to be performing well.

The Uniformity Coefficient (Cu) was first proposed by Christiansen (1942) and is defined as:

$$C_u = 100\,(1 - \frac{M}{\bar{x}})$$

where M is the mean absolute deviation of the applied water depths $\bar{x}_i$ (or catch-can depths from sampling grid) and is given by:

$$M = \frac{\sum |\bar{x}_i - \bar{x}|}{n}$$

where $\bar{x}$ is the mean applied depth and n is the number of measurements. For systems that have a considerable variation in uniformity, there will be large variations from the mean and the coefficient will decrease. Solid set sprinkler systems that have a Cu less than 86% would typically be viewed as under-performing while CP&LMs would be expected to have a Cu greater than 90% to be considered acceptable.

Heermann and Hein (1968) proposed a measure of application uniformity that should be used specifically for centre pivot machines. In this measure, the applied depths are weighted according to their radial position along the length of the machine, to allow for the different annular area represented by each depth. The modified Heermann and Hein (1968) coefficient of uniformity can be written as:

$$C_u = 100\left[1.0 - \frac{\sum_s S_s\,|D_s - \bar{D}|}{\sum_s D_s S_s}\right]$$

where D_s is the applied water depth for one collector position, $\bar{D}$ is the average applied water depth for all collectors, and S_s is the distance to equally spaced collectors.

Marek et al. (1986) and Bremond and Molle (1995) introduced other areal weighted uniformity coefficients specifically for centre pivot machines. Both of these methods use the square of the differences from the mean, rather than mean deviation as used by Heermann and Hein (1968). These methods emphasise any significant deviations from the mean and are useful in highlighting the poor performance of broken or blocked emitter nozzles. A number of researchers (for example, Heermann 1994; Smith 2000) have also suggested that representing the irrigation variation using a cumulative irrigation depth distribution curve may better describe the performance of an irrigation system than the use of a simple coefficient.

Application efficiency

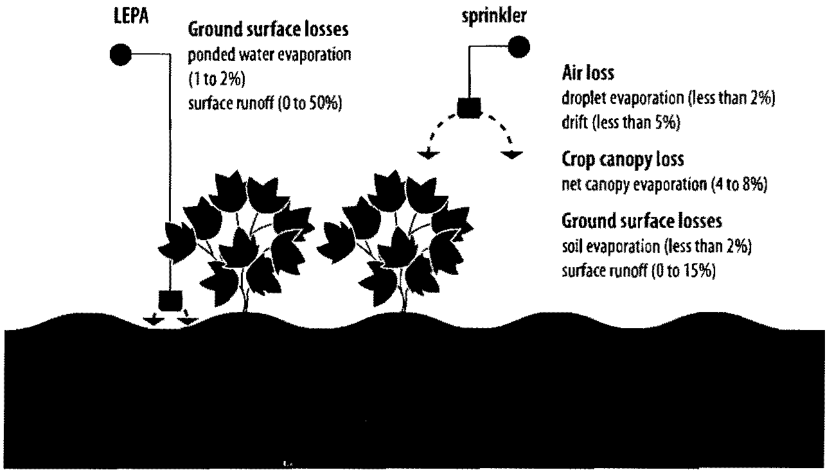
The **application efficiency** (AE) is a measure of the losses associated with applying water to a field. It is calculated as the ratio, expressed as a percentage, of the volume of irrigation water stored in the root zone divided by the volume of water supplied to the field inlet (IAA 1998). The loss mechanisms that decrease application efficiency for CP&LMs include:

- sprinkler loss of fine water droplets
- evaporative losses from either the soil surface or plant surfaces
- run-off from the irrigated field; and
- deep drainage.

As with other forms of irrigation, run-off and deep drainage are most commonly associated with poor management and system operation. However, wind drift and evaporative losses are strongly influenced by emitter selection, nozzle size, operation pressures, and emitter location in relation to the crop canopy and weather conditions. A large number for studies have been conducted in the USA (for example, Silva and James 1988; McLean et al. 2000; Yonts et al. 2000a&b) to quantify evaporative losses under a range of conditions, and compare the efficiency of the various emitter options. Older style low angle, high pressure impact sprinklers located above the pipe have been found to commonly operate with efficiencies of 70% to 85% (for example, Schneider and Howell 1999; Harrison 1995). However, low pressure, static plate sprinklers commonly operate at between 80% to 90% application efficiency while the moving plate sprinklers have application efficiencies up to 95%. LEPA socks and bubbler emitters have been found to have application efficiencies up to 98% where surface run-off is controlled. However, up to 50% run-off has been found (Schneider 2000) where LEPA systems are operated under adverse conditions without furrow dyking.

Evaporative losses are not well understood by Australian growers using irrigation. Drift and evaporation losses of sprinkler droplets (Figure 4.6.8) using a typical CP&LM sprinkler configuration (nozzle pressure=138 kPa, nozzle diameter=4.7625 mm) are commonly reported as less than 5% and rarely greater than approximately 8%, even under extreme weather conditions (relative humidity = 10%, dry bulb temperature = 43°C, wind speed = 19 km/h, for example, Frost and Schwalen 1960). Similarly, evaporation losses from the crop canopy surfaces may be as small as 1% to 2% (New and Fipps 1995; Yonts et al. 2000a) and are commonly reported as less than 8% (Schneider and Howell 1999). Hence, moving the emitter into or below the crop canopy may not necessarily increase application efficiency dramatically and may result in greater run-off water losses due to the increased IAR associated with the smaller wetted area.

Figure 4.6.8. Illustration of the water loss pathways for LEPA and sprinkler application methods under CP&LMs



Source: from Schneider 1999

Designing the system capacity of CP&LMs

Furrow irrigating cotton growers continue to install more centre pivots and lateral moves (CP&LMs) every year. The main reasons given for the adoption of CP&LMs are the reduction of irrigation labour requirements of 80% over that used for traditional furrow irrigation, the greater control of soil moisture, the 1 bale/ha average potential yield increase due to reduced crop waterlogging, the greater beneficial capture of in-crop rainfall, the overall simplicity of use and the 30% to 50% reduction in applied water possible over traditional furrow irrigation.

System capacity is the most important design parameter for CP&LM machines in the Australian cotton industry. Many machines installed in Australia in the past do not have a system capacity large enough to ensure cotton crop success. The problem of low system capacity has been the single greatest reason for the continuing low uptake of CP&LMs in Australia, and only if they can supply water onto irrigated cotton fields at a rate great enough to cater for peak crop evapotranspiration rates can they succeed in the Australian cotton industry.

The highly variable climate in which the Australian cotton industry operates means that timely and beneficial rainfall cannot be relied upon to help irrigation systems during peak crop water requirement. No benefit can then be allocated to rainfall supplementing irrigation during that period when the crop most requires water and is not included in any of the following analyses.

This discussion assumes that growers have an adequate volume of water allocated for the irrigated area underneath their CP&LM. Understanding your water resources is important, and other authors in WATERpak have addressed this issue.

Calculating the system capacity of your CP&LM

To calculate your system capacity, take the flow rate of water pumped by your CP&LM installation and divide by the area of crop that the CP&LM will cover in any one cotton season.

Example 1: LM system capacity

A lateral move is capable of pumping 300 litres per second onto 180 ha in a day – what is the system capacity?

Volume applied (L/day) = 300 L/s × 60 s/min × 60 min/hour × 24 hours

= 25 920 000 L/day

Area irrigated (m^2) = 180 ha × 10000 m^2/ha

= 1 800 000 m^2

System capacity (mm/day) = volume applied (L/day) ÷ area irrigated (m^2/day)

= 25 920 000 L/day ÷ 1 800 000 m^2/day

= 14.4 L/m^2

≈ 14.4 mm/day (as 1 L/m^2 = 1 mm)

Alternatively, divide the CP&LM flow rate in ML/day by the area in hundreds of hectares, that is, 25.92 ML/day divided by 1.8 hundred hectares equals a system capacity 14.4 mm/day.

Example 2: Large lateral move capacity

A large lateral move runs along a supply channel that is 6600 metres long. The overall length of the lateral move machine is 1008 metres and the width of irrigated field underneath the lateral move is 984 metres. The pump flow rate for this lateral move is 300 L/s or 25.92 ML/day. If two 800 metre long fields, back to back, are used to grow cotton in one season, then what is the system capacity?

Volume applied (L/day) = 300 L/s × 60 s/min × 60 min/hour × 24 hours

= 25 920 000 L/day

Area irrigated (m^2) in a single cropping season = 984 m × 800 m × 2 fields

= 1 574 400 m^2

System capacity (mm/day) = volume applied (L/day) ÷ area irrigated (m^2/day)

= 25 920 000 L/day ÷ 1 574 400 m^2/day

= 16.46 L/m^2

≈ 16.5 mm/day (as 1 L/m^2 = 1 mm)

Example 3: CP system capacity

Calculate the system capacity of a 496 metre long centre pivot, that is, 10 x 48 m spans + 16 m overhang with a pump flow rate of 141 litres per second

Volume applied (L/day) = 141 L/s x 60 s/min x 60 min/hour x 24 hours

= 12 182 400 L/day

Area irrigated (m^2) = π x radius^2

Where, π = 3.14

radius = 496 m

Therefore, Area = 3.14 x 496 m x 496 m

= 772 490 m^2 or 77.249 ha

System capacity (mm/day) = volume applied (L/day) ÷ area irrigated (m^2/day)

= 12 182 400 L/day ÷ 772 490 m^2/day

= 15.77 L/m^2

≈ 15.8 mm/day (as 1 L/m^2 = 1 mm)

Alternatively, the flow rate, 12.1824 ML/day divided by 0.77249 hundred hectares = 15.77 ML per hundred hectares per day = 15.77 mm/day.

This is how to calculate the system capacity of CP&LMs. It is a very important design parameter and is the maximum possible flow rate the machine can apply onto the irrigated area. Remember this is not the amount of water applied per irrigation pass.

Managing CP&LM system capacity

The system capacity is the maximum possible flow rate that the CP&LM can apply to the area of an irrigated field. The system capacity of a CP&LM is reduced considerably in the real world by the number of hours that the pump is turned off during any given irrigation cycle. The amount of time the pump is running during any irrigation cycle is called the **pumping utilisation ratio**.

The pumping utilisation ratio can be calculated from the average number of pumping hours per day divided by 24 (or divide the total hours of pumping over a 10-day period by 240 hours, let's say 204 ÷ 240 = 0.85). Remember to take into account the non-irrigating time necessary for any pesticide spraying with over-crop sprinklers and the dry travel time of the CP&LM that you think that you may need.

System capacity is further reduced by losses that occur when the water travels from the nozzle on the machine into the crop root zone. This ratio of the water that actually makes it into the crop root zone divided by the total amount of pumped water is called the **application efficiency** (see earlier discussion). For LEPA systems, choose an application efficiency of 0.98, and for modern over-crop sprinkler systems choose a value between 0.9 and 0.95. As an example, a grower running a CP&LM pump for 204 hours throughout a 10 day period during peak crop water use period, using a well-tuned over-crop sprinkler system, would be able to irrigate at a rate of 0.85 × 0.95 = 0.81 of the system capacity.

In a worst case scenario you might have a system capacity of 14 mm/day, but if the pump only ran for 0.75 of the time, even with a LEPA system, then on average 10.5 mm/day would be applied into the crop root zone.

Remember that these system capacity values have nothing whatsoever to do with the amount of water applied by the CP&LMs during each irrigation pass. The amount of water that is applied per pass is governed by the pump flow rate and the amount of time that the machine takes to complete one irrigation pass of the complete irrigated area. Just as a constant flow rate boomspray operator would reduce speed to apply a greater amount of water to the field, so too is the average speed of a CP&LM reduced to apply more water per pass.

For example, a centre pivot grower using good over-crop sprinklers with a system capacity of 14 mm/day, decided to set the machine speed so that the centre pivot took 2.5 days to irrigate the full circle, and then stop the machine for 0.5 day before restarting the machine. Under this management, the centre pivot would apply 14 mm/day x 2.5 days/pass x 0.95 = 33.25 mm for that irrigation.

Calculating the water applied into the crop root zone

A large lateral move is designed with LEPA socks and a pump flow rate of 300 L/s with an irrigating width of 984 metres. The pump will run for 8.5 days out of 10 during peak crop evapotranspiration period. This downtime of 1.5 days includes time where the machine is being shifted across ends of fields or returning to the dry end of the field, or while aerially sprayed pesticides are being applied to the crop. The LEPA lateral move runs across two fields that are 900 metres long for a total cropped field length of 1800 metres. The average amount that the machine will apply into the crop root-zone per day will be:

Average amount applied

$$= \frac{\text{volume applied(L/day)} \times \text{pumping utilisation ratio} \times \text{application efficiency}}{\text{area irrigated (m}^2\text{)}}$$

$$= \frac{300\ \text{L/s} \times 3600\ \text{s/h} \times 24\ \text{hrs/day} \times 0.85 \times 0.98}{984\ \text{m} \times 1800\ \text{m}}$$

$$= \frac{21\,591\,360\ \text{L}}{1\,771\,200\ \text{m}^2}$$

$$= 12.19\ \text{L/m}^2$$

$$\approx 12.2\ \text{mm/day}$$

Alternatively, the 300 L/s equals 25.92 ML/day, and calculating how much water this will apply into the root zone per day over the 177.12 ha is given by 25.92 ML/day × 0.85 × 0.98 divided by 1.77 hundred hectares = 12.19 mm/day.

Choosing a system capacity for your CP&LM

A common question raised by many cotton growers who are contemplating the installation of CP&LMs is 'what system capacity should my CP&LM have on my field?' A process for choosing a suggested CP&LM system capacity has been developed using the evapotranspiration maps of Australia recently developed by the CRC for Catchment Hydrology and the Bureau of Meteorology under their technology transfer program (Wang et al. 2001) (see Topic 2.12).

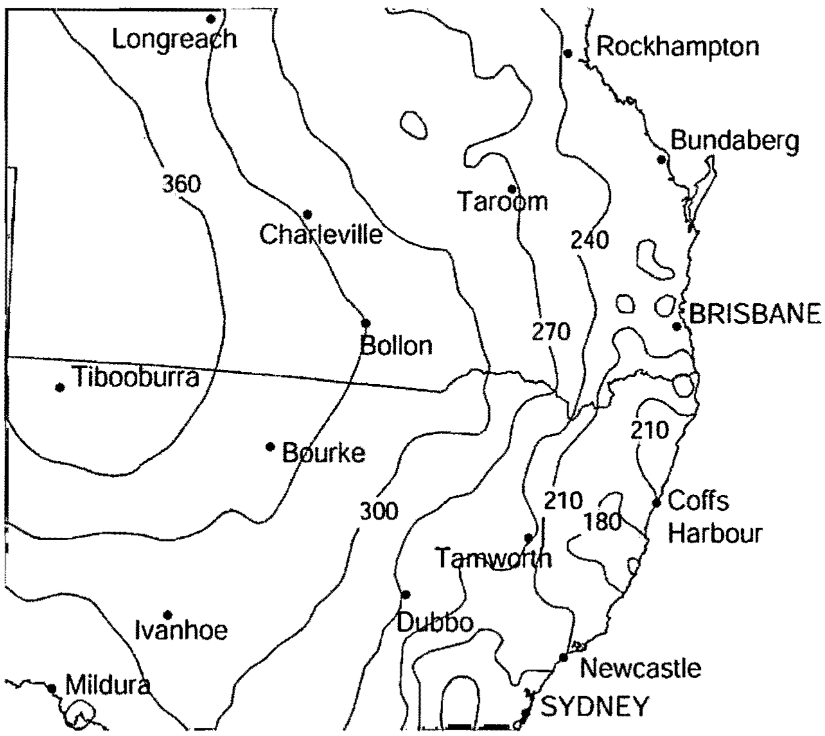
A calibration factor has been derived, from the system capacities of CP&LMs across the cotton industry and the January map of average point potential evapotranspiration (ET_0), to allow growers to choose their location and calculate their own system capacity. This calibration factor was developed by using previously recorded system capacities for CP&LM installations across a number of regions in the cotton industry.

The ET_0 map for January was chosen as it represents the period of greatest crop water use for cotton. The calibration factor takes into account the conversion of the monthly average value to the more useful 3 day peak ET_c value and assumes a pumping utilisation rate of 0.85 and the use of a LEPA system with an application efficiency ratio of 0.98.

The proposed process involves initially locating the proposed site of your CP&LM on the point potential evapotranspiration map for the month of January, provided in Figure 4.6.9. The second step is to then interpolate for the value from the closest lines of evapotranspiration for your particular location and divide the value by the cotton industry system capacity calibration factor for cotton-growing CP&LMs of 21.5. The resulting number will be in millimetres per day, and is a starting point for grower's decisions regarding the appropriate system capacity for their CP&LM design.

If growers are concerned about the particular value they calculate, consult appropriately skilled irrigation professionals. Note that the mapped lines of equal potential evapotranspiration are in incremental steps of 30 mm.

Figure 4.6.9. January monthly average point potential evapotranspiration map for Australia's existing cotton-growing regions



Source: Wang et al. 2001. Originally developed by the CRC for Catchment Hydrology and Bureau of Meteorology, based on data from 1961 to 1991.

A similar process was recently used by the original authors of the evapotranspiration maps to develop an understanding of the complete range of evapotranspiration rates across the state of Victoria.

For example, a cotton grower wishes to install a centre pivot at Bollon, which lies on Figure 4.6.9 at the 330 mark. Divide 330 by 21.5, and the suggested system capacity is 15.3 mm/day. This would be the system capacity a grower would install when the pumping utilisation ratio is 0.85 and the application efficiency is 0.98.

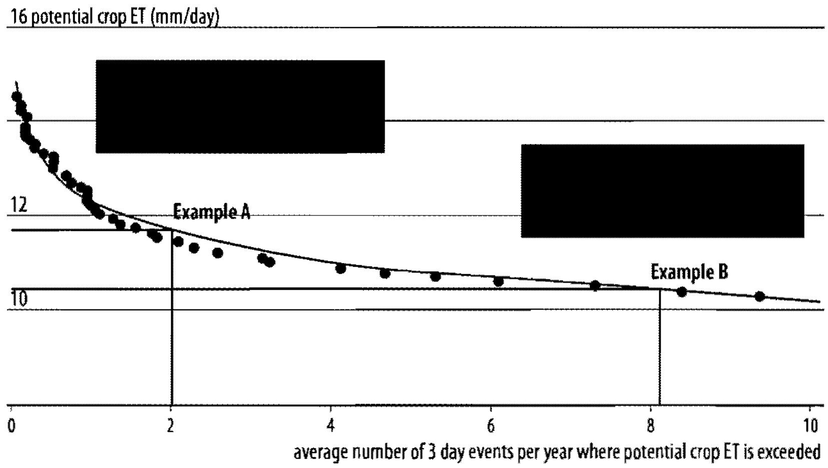
How does your CP&LM system capacity compare to a 3-day peak crop evapotranspiration rate?

In trying to understand whether or not a particular system capacity for a CP&LM will adequately cater for the peak crop water requirements of a fully grown cotton crop, consider the evapotranspiration rates that would be likely to occur in any given crop growing season at a particular location.

If we were to undertake an analysis of the evapotranspiration for the St George region, the chances of having a 3-day average potential crop ET value greater than a certain size would look like the information detailed in Figure 4.6.10. When growers choose a certain system capacity for a CP&LM installation in the St George region, for example, they are essentially choosing the number of days per year where the potential crop ET will be greater than the chosen system capacity of the CP&LM installation. The nature of potential crop evapotranspiration is such that there is always the possibility in any year of a number of the days where high evaporation occurs.

The number of days per year where potential crop evapotranspiration is greater than the rate at which water can be supplied by the irrigation system needs to be reduced by choosing CP&LM system capacities capable of handling these extremes. It does not matter how large a CP&LM system capacity you choose, there will always be a day where peak crop evapotranspiration is greater.

Figure 4.6.10. Recurrence of 3-day peak crop evapotranspiration rates for the St George region



From the X-axis, consider the number of times per year where corresponding potential crop ET will be exceeded and then choose your own appropriate CP&LM system capacity.

Understanding how many extreme 3-day peak crop evapotranspiration events per year will occur allows growers to determine their own level of risk in relation to their chosen CP&LM system capacity. In effect, when growers choose their irrigation system capacity, they are choosing the level of risk that the machine will not be able to keep up with particularly high evaporative days. Growers who are not prepared to risk the possibility that their CP&LM will 'not keep up' choose larger CP&LM system capacities. The real consequences of choosing lower system capacities will be the reduction in the average amount of water held in the crop root zone as each passing day extracts on average more than the CP&LM system capacity can supply. This does not necessarily mean crop failure, but rather the gradual decline in the readily available water supply for the crop and the potential for crop yield reduction.

For example, if the average 3-day peak crop evapotranspiration rate was 14.5 mm/day and the CP&LM LEPA system capacity was 12 mm/day with continual operation, the average moisture content would decrease by 2.5 mm every day, and over 3 days this would create a total soil moisture deficit of 7.5 mm average across the entire field. This will not necessarily mean crop failure, but may lead to crop yield reduction.

A complete analysis of possible CP&LMs system capacities and resulting irrigated crop performance in relation to regional peak crop potential evapotranspiration rates is only possible through the use of a crop model used for long-term climatic data in various growing regions with a wide range of system capacities.

Increased capital costs associated with larger CP&LM system capacities do not necessarily increase in proportion to system capacity. For large lateral moves, whose upper size limit is currently controlled by the maximum flow rate of the largest pumps that manufacturers are prepared to place upon drive carts (typically a Cornell 10 RB @ 300 L/s), increasing the system capacity can be changed by decreasing the overall irrigated run length irrigated in any one season. This is a cost-effective and simple matter as no substantial change to the lateral move design is necessary. However, costs could be incurred if changes are necessary to the field drainage network.

Increasing centre pivot system capacities involves changes in the nozzle set, imposing a very minor cost. More importantly, however, alterations in the pump and pipe diameters, both in the span and supply line, can have significant associated costs. If pumps and pipes are incorrectly designed, the lifetime running costs of the system can be greatly increased.

Remember that choosing larger system capacities for CP&LMs does not mean that larger water volumes are applied to the crop. Choosing greater system capacities for CP&LMs simply means that there is adequate capacity to cater for the peak crop water requirements of well-grown cotton when the crop requires it most. As one cotton grower saying goes 'Change the things you can, and don't worry about the rest'.

Recent purchases of large lateral moves in the cotton industry have all been with the largest pump flow rate possible for these machines. There currently exists an upper pump size limitation to the flow rates possible through the larger lateral moves. This is based upon the largest flow capacity from the Cornell 10 RB, a highly efficient double volute pump preferred by the small number of companies building larger lateral moves. Based upon this fact, a range of different field lengths have been calculated and are presented in Table 4.6.1.

Table 4.6.1. Lateral move field lengths for various irrigating widths and system capacities

Pump flow rates of 300 L/s, pump utilisation ratios 0.85 and 0.95 and an application efficiency ratio for LEPA of 0.98.

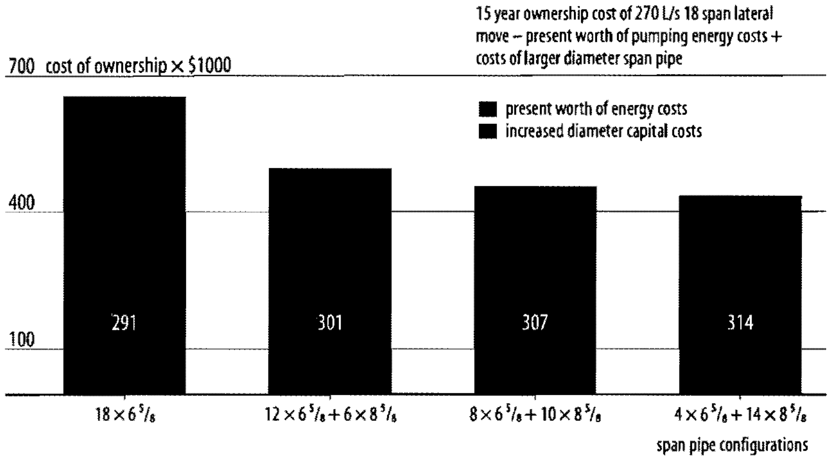
700	8.5	2570	2200
	9.5	2870	2460
750	8.5	2400	2050
	9.5	2680	2300
800	8.5	2250	1920
	9.5	2510	2150
850	8.5	2110	1810
	9.5	2360	2020
900	8.5	2000	1710
	9.5	2230	1910
950	8.5	1890	1620
	9.5	2110	1810

Running costs of CP&LMs – implications of poor hydraulic design

One of the largest costs of ownership of CP&LMs is the on-going pumping energy cost associated with supplying irrigation water through the machine. Many growers who have purchased CP&LMs in the past have not completely understood the implications of purchasing equipment with small pipe span diameters. Consequently, their overall cost of ownership was drastically increased when they purchased a slightly cheaper pipe span configuration. It is important to understand how increasing the overall upfront capital costs slightly can drastically reduce long-term ownership costs.

A present worth analysis of the long-term pumping energy costs of a large lateral move with four different configurations was conducted, as shown in Figure 4.6.11. This analysis translates the future costs of pumping energy involved with the lateral move into today's dollars. The analysis was carried out over a 15-year lifetime, with 835 ML being applied per annum through the lateral move. Pumping energy costs were $0.75/ML/m head; an interest rate of 7% was used for this example. All spans available for this analysis were 48 metres long and two different diameter pipe spans were used as $6^{5}/_{8}$" and $8^{5}/_{8}$" nominal diameters. (Pipe diameter terminology is in keeping with current industry practice.)

Figure 4.6.11. Cost of ownership for long-term energy costs and up-front capital for four different 18 span lateral move designs with numbers of larger diameter span pipes from 0, 6, 10 and 14



The lowest cost option of the four different lateral move designs consists of 18 small diameter spans. The most expensive design consists of 14 spans of the larger diameter pipe spans. The economic and hydraulic modelling used to generate Figure 4.6.11 shows that increasing the number of spans with large pipes costs an additional 7.9%, but reduces the 15 year pumping energy costs to one-third of that from the lateral move with all small diameter pipe spans.

Similarly, when the analysis is conducted for a 10 span centre pivot, under the same economic modelling conditions, the analysis shows that a 6.4% increase in capital costs can reduce the overall pumping energy costs to one-half of that of a centre pivot with all small diameter pipe spans (see Figure 4.6.12).

These long-term ownership costs contrast with typical US designed centre pivot installations with lower overall machine flow rate, where there is a very small difference in the long-term ownership costs, as shown in Figure 4.6.13.

Figure 4.6.12. Ownership costs for long term energy costs and up-front capital for four different 10 span centre pivot designs with system capacity of 14 mm/day with the number of larger diameter span pipes increasing from 0, 3, 5 to 7

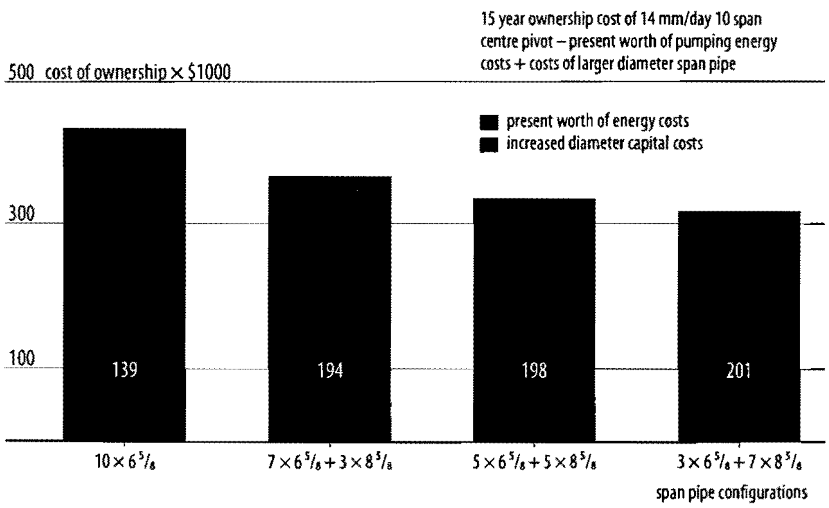
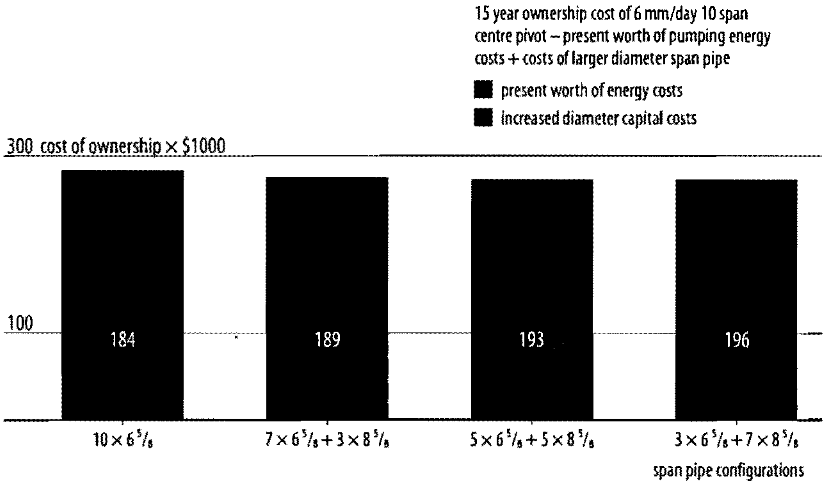


Figure 4.6.13. Ownership costs for long term energy costs and up-front capital for four different 10 span centre pivot designs with system capacity of 6 mm/day with
Figure 4.6.13. Ownership costs for long term energy costs and up-front capital for four different 10 span centre pivot designs with system capacity of 6 mm/day with
the number of larger diameter span pipes increasing from 0, 3, 5 to 7



Practical management tips for CP & LMs

Cotton crop growth management

Management of cotton crop growth under CP&LMs can prove to be difficult for many who normally operate with furrow irrigated crops. Cotton crops under these machines do not suffer from the significant waterlogging and crop growth reduction that occurs with furrow irrigation. This means that crop growth is not slowed and adjustments to the application of plant growth regulators, such as Pix, need to be made. Growers and agronomists should operate under the principle of 'Go early, go heavy and go often.'

Wheel track and wheel rut management

One of the most important issues any new grower faces in the first few years of owning and managing CP&LMs relates to wheelruts and wheeltrack management. Few issues are more bothersome for a grower, but few are less discussed by dealers and manufacturers than the issue of wheel track and wheel rut management.

There are a number of things that growers can insist upon in the design of CP&LMs that will lessen the anxiety many growers feel in relation to this troublesome issue:

- Boombacks upon wheel towers direct irrigated water to that part of the field behind the travelling machine, allowing the tower to run upon dry ground. Ensure that the boomback reaches a great enough distance behind the wheel tower to minimise the water thrown up on it.

- Use half-throw sprinklers on solid drops immediately around the towers to ensure water is not thrown directly into the ground, as is the case with soft hose droppers.
- Consider reducing nozzle sprinkler flow rates immediately adjacent to towers to 80% of their existing flow rates.
- Larger tyre and wheel sizes are more commonly installed on CP&LMs today and many growers are successfully conducting trials where three and four wheels are driven inline upon the tower base, instead of the traditional two. Track and dreadnought options abound in the US.

A number of factors are important to remember when initially managing a new CP&LM. As the first seasons pass, significant wheel track compaction levels rise and wheel rutting issues tend to decrease. This compaction is a significant help to the operation of your machine under saturated soil conditions and it is important to consider leaving it alone during deep ripping operations.

Managing germination under sprinkler irrigation

All growers using CP&LMs will use sprinklers to germinate their crop, and it is essential that growers understand some of the ways that this can be successfully carried out. During this germination phase, consider using a second nozzle set that reduces the total machine flow rate through the pump. This is sometimes called a dual nozzle pack and is one of the cheaper options that growers can employ to successfully apply water softly to freshly cultivated soils without inducing crusting and causing seedling emergence issues. A number of growers also plant dry and irrigate the crop up with a number of light slow sprinkler irrigations. A number of light slow irrigations throughout the germination period can also assist crops to move through soils prone to crusting.

LEPA irrigation systems

After germination and crop establishment, some growers employ LEPA systems to apply water throughout the rest of the crop life. When growers move to LEPA systems they need to remember that water is now being applied at much higher application rates than any soil is capable of retaining at the time of application. A critical part of the original LEPA system was to build a retention system into the soil before using the LEPA heads. This involves building small dams or dikes in the furrow between crop rows to capture the water applied at a very high rate. The original system developed in Texas was built for irrigation systems that are supplementary in nature and was only designed for machines with system capacities in the order of 5 to 7 mm/day. This means that while trying to use LEPA systems in Australia upon machines with system capacities of 14 mm/day, we are essentially using these systems at over twice their originally designed capacities. Growers need to ensure that while they are operating LEPA systems on CP&LMs at these high system capacities that the soil being irrigated has the retention capacity in the form of significant cracking or soil surface roughness to hold water where it is placed. Alternatively, growers need to consider the correct implementation of dikes and small dams in alternate rows as part of the normal field preparation process for the use of LEPA irrigation systems.

Ensuring longevity from your CP&LM investment

One of the simplest ways to ensure that CP&LMs remain cost-effective is to ensure their longevity. Some of the greatest risks associated with the longevity of the valuable investment that you have made in the CP&LM irrigation system come from the natural world. Provided below are a number of practical tips to ensure the longevity of your CP&LM investment.

Corrosion – ensure that, if the water quality tests that your dealer has analysed prior to purchase suggest that the standard galvanised machine will be prone to corrosion, you invest in machines that are constructed of material that is resistant to corrosion. An additional 5% upfront investment in the capital cost of the machine can mean up to a five-fold increase in the life of the machine.

Ensure that, regardless of the water quality used in the machine, all water is drained from the lowest points of the spans: some span drain designs do not allow this, and other designs include automatic valves that have variable operational success. One alternative is to plumb this low span drain point out to a tee placed into the second or third sprinkler dropper. This overcomes both the tower and wheeltrack flooding at irrigation shutdown and ensures that there is no valve to become blocked by irrigation sediment.

The risk from overland flooding with CP&LMs is minimal, except through flooded areas where fast moving water exists. Some growers install earthen berms (mounds of soil) raised above the flood-prone field level that allow growers to park the machine above the level of the floods. Gearboxes should be drained and refilled with new oil after inundation and electric control panels professionally cleaned and checked by professionals if they become immersed.

A number of CP&LMs have been damaged by violent windstorms over the history of their use in Australia. A number of practical techniques can be employed by growers to prevent and or lessen the damage. Anecdotal evidence from machine constructors on-site during a violent wind storm report that the machine developed a bouncing action which threatened to loosen truss rods and collapse the recently built spans. The action of the wind past the round main pipe span was inducing vortices which alternately forced the main pipe up and down, causing the whole span to develop a wild bouncing action. Purchasing low-profile towers for low growing crops means that the span intercepts lower general wind speeds closer to the ground, in any wind event. Some growers park their centre pivots so that the centre point is directed into the prevailing storm path. Other growers operate their pumps and fill their machines with water to increase the weight and reduce the risk of these machines being moved by wind. Another option is to employ tie-down points at the end of field or on access roads. These can consist of submerged earth anchors such as large buried concrete blocks, vertically placed railway iron or wooden piles placed at intervals equal to span spacings, which have cable or chain attached to tie down span towers.

Modern tower gearboxes contain gas expansion chambers (flexible rubber diaphragm enclosed within steel enclosures) that allow for the expansion and contraction of the gases and liquids in the gearbox during heating and cooling, without creating differential pressure upon the axle seals. This design does not allow suction pressure to build up on the axle seals of the gearbox when it is cooled during sprinkler irrigation, thus preventing water being drawn into the gearbox to corrode drive trains. In any instance, ensure that sump plugs are regularly removed and water is drained from gearboxes. CP&LM manufacturers specify gearbox oils that have properties allowing water to separate from oil and settle to the bottom of the gearbox.

Towable gearboxes are available in a number of different designs, with the older style having caused enormous difficulty for growers over the years. The original design contains a second set of bearings that are positioned outside the original axle of the gearbox. They are configured so on removing a single pin, the wheel hub disengages from the gearbox axle. This allows free rotation of the wheel during towing of the centre pivot from one site to another upon this secondary bearing system. Over time the pin and secondary bearings wear and allow movement of the wheel hub upon the gearbox axle, resulting in a failure of the gearbox drive train. More modern designs allow the worm gear to be physically disengaged from the bull gear in the gearbox, so that the wheel hub remains attached to the original gearbox drive axle. They do not use a secondary set of bearings within the drive-line.

Ensure that you flush the main span pipes on a regular basis, especially if you are using any surface water or groundwater bores that are pumping sand. This will ensure that excessive sediment weight is removed from the spans, particularly overhangs, where this material tends can accumulate and induce additional loading stresses. Corrosion that can occur underneath these saturated sediments upon the wall of galvanised pipes can lead to early pipe failure. Many growers install large valves upon the end of the overhang and last spans to allow higher water velocities to scour sediment from the pipe spans when the valve is opened.

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